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XUM

THE

National Geographic Magazine

AN ILLUSTRATED MONTHLY

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The list of contributors to the NATIONAL GEOGRAPHIC MAGAZINE includes nearly every United States citizen whose name has become identified with Arctic exploration, the Bering Sea controversy, the Alaska and Venezuela boundary disputes, or the new commercial and political questions arising from the acquisition of the Philippines.

The following articles will appear in the Magazine within the next few months:

"Russia," by Professor Edwin A. Grosvenor of Amherst College, Massachusetts.

"The Venezuelan Boundary," by Mr Marcus Baker of the Venezuelan Commission.

"The Samoan Islands," by Mr Edwin Morgan, Secretary of the Samoan Commission.

"The Native Tribes of Patagonia," by Mr J. B. Hatcher of Princeton University.

"British South Africa and the Transvaal," by Col. F. F. Hilder, Bureau of American Ethnology.

"The Characteristics of the Filipinos," by Hon. Dean C. Worcester of the Philippine Commission.

"Discoveries in the Fossil Fields of Wyoming in 1899," by Prof. Wilbur C. Knight of the University of Wyoming.

"Explorations on the Yangtse-Kiang, China," by Mr Wm. Barclay Parsons, C. E., surveyor of the railway route through the Yangtse-Kiang Valley.

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BASALT CANON, PLAINS OF PATAGONIA — SHOWING REMNANT OF A COMPARATIVELY RECENT LAVA FLOW

From a photograph by J. B. Hatcher

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SOME GEOGRAPHIC FEATURES OF SOUTHERN PATAGONIA, WITH A DISCUSSION OF THEIR ORIGIN

By J. B. HATCHER

Princeton University

In the following pages I shall attempt to describe in as clear and concise a manner as possible the principal geographic features of that part of Patagonia lying beyond the 46th parallel of south latitude as they presented themselves to me during my travels in that country the past three years while engaged chiefly in paleontologic and geologic researches in behalf of Princeton University. I shall also give a brief description of the geology of the region as a basis for a more extended discussion concerning the agencies which have contributed to produce the existing somewhat unusual, not to say unique, drainage systems of Patagonia. I shall not attempt an itinerary of my explorations, in the progress of which I crossed and recrossed the southern extension of the continent in many directions, nor shall I undertake to describe in detail the geography of any particular part of the region.

The attention of the traveler in Patagonia, if he is endowed with any of the instincts of a naturalist, is first attracted to the long line of cliffs that everywhere on the eastern coast rise boldly from the sea to a height of from 300 to 500 feet. While still far out at sea this is discernible to the experienced eye of the navigator, though to the landsman it may appear as a low cloud or fog-bank, to either of which illusions its usually unbroken summit and dull gray colors freely lend themselves. As the vessel approaches some one of the few harbors of this coast, commonly located at the mouths of rivers, its true nature soon becomes apparent, and it develops as a great sea

wall stretching far away on either hand until lost in the northern and southern horizons. This line of bluffs extends throughout the entire eastern coast of Patagonia, with but occasional interruptions at the mouths of the few rivers that, flowing eastward from the Andes across the plains, discharge their waters into the Atlantic.

The rocks forming the cliffs consist of alternating layers of sandstones and clays, approximately though not entirely horizontal, of a prevailing light brown or gray color, and everywhere remarkably free from any faults or other disturbances. Although the color and lithological characters of the rocks are quite similar throughout the entire coast line, yet there is a decided difference in their age and origin, as shown by the fossils contained in them. Toward the north the entire series of strata belong to the Patagonian beds, of Middle Tertiary age and marine origin, and contain in great abundance the fossil remains of oysters, pectins, brachiopods bryozoans, etc., together with occasional bones and skulls of whales, dolphins, and other cetaceans, all bearing unimpeachable evidence as to their marine nature.

These marine beds attain their maximum development in the region of San Julian, where they show a thickness of 900 feet. From this point they dip very gently to the southeast, as is demonstrated by the fact that the succeeding strata gradually disappear beneath the waters of the Atlantic as we proceed southward along the coast. So slight, however, is this southerly dip that for more than 100 miles only the Patagonian beds are seen in the bluffs; but at a point about 40 miles south of the Santa Cruz River a second series of rocks of somewhat lighter color and composed of usually softer materials appear at the summit conformably overlying the Patagonian beds.

This second series of strata constitutes the Santa Cruz beds, of lacustrine and æolian origin. It contains the remains of that rich and unique assemblage of fossil birds and mammals concerning the age and relations of which there has been such wide discussion. Continuing southward along the coast the rocks of the Santa Cruz beds dip gently to the southeast, so that in the region of Coy Inlet their lowermost strata have reached the water level, while the entire series forming the Patagonian beds are here submerged beneath the waters of the Atlantic.

South of Coy Inlet, as far as Cape Fairweather, the bluffs are entirely composed of the Santa Cruz beds. At Cape Fairweather another series of rocks appears at the summit unconformably overlying the Santa Cruz beds and designated as the Cape Fairweather

beds. They are of marine origin and contain, in great abundance, the remains of marine invertebrates. I should also add that throughout the entire extent of this coast the uppermost crest of the bluffs is composed of from 20 to 30 feet of unstratified boulders and clays, constituting the great Shingle formation of Patagonia, distributed somewhat uniformly over almost the entire surface, and of probably combined ice and aqueous origin.

With this hasty survey of the eastern coast line, let us proceed into the interior. Ascending the bluff we emerge upon a broad, elevated plain, stretching westward to the base of the Andes and abruptly terminated on the east, as we have seen, by the lofty escarpments of the sea. Its surface, with a thin veneer of soil vainly endeavoring to conceal the rocks beneath, is scantily covered with grass. Occasional bushes, seldom attaining a height of more than five or six feet, appear in specially favored localities. Bands of guanaco, or South American camels, and flocks of rheas, the so-called ostrich, feed here in great numbers and provide the chief sustenance of the Patagonian traveler, as also of the Patagonian Indian.

Scattered over the surface of the plains in considerable numbers are great depressions, or rather excavations, frequently several miles in diameter and from 100 to more than 1,000 feet in depth, as observed in some instances near the base of the Andes. The bottoms of these depressions are usually occupied by small saline lakes. In periods of drought, which occur annually in this region, usually from December to April, the volume of water in such lakes is much reduced by evaporation, and beds of almost pure salt are precipitated, occasionally attaining a thickness of several feet.

An examination of the depressions occupied by such lakes reveals the fact that the bluffs on one side are always much lower than those on the other sides, and, further, that the lower side always lies toward the present drainage system of the particular region in which the lake is situated. All this leads to the inference that these are residuary lakes, left as confined bodies of water at the final elevation of the land above sea-level, and, further, that the depressions are remnants of former drainage systems, existing prior to the last submergence, and corresponding approximately, though not entirely, with those of today.

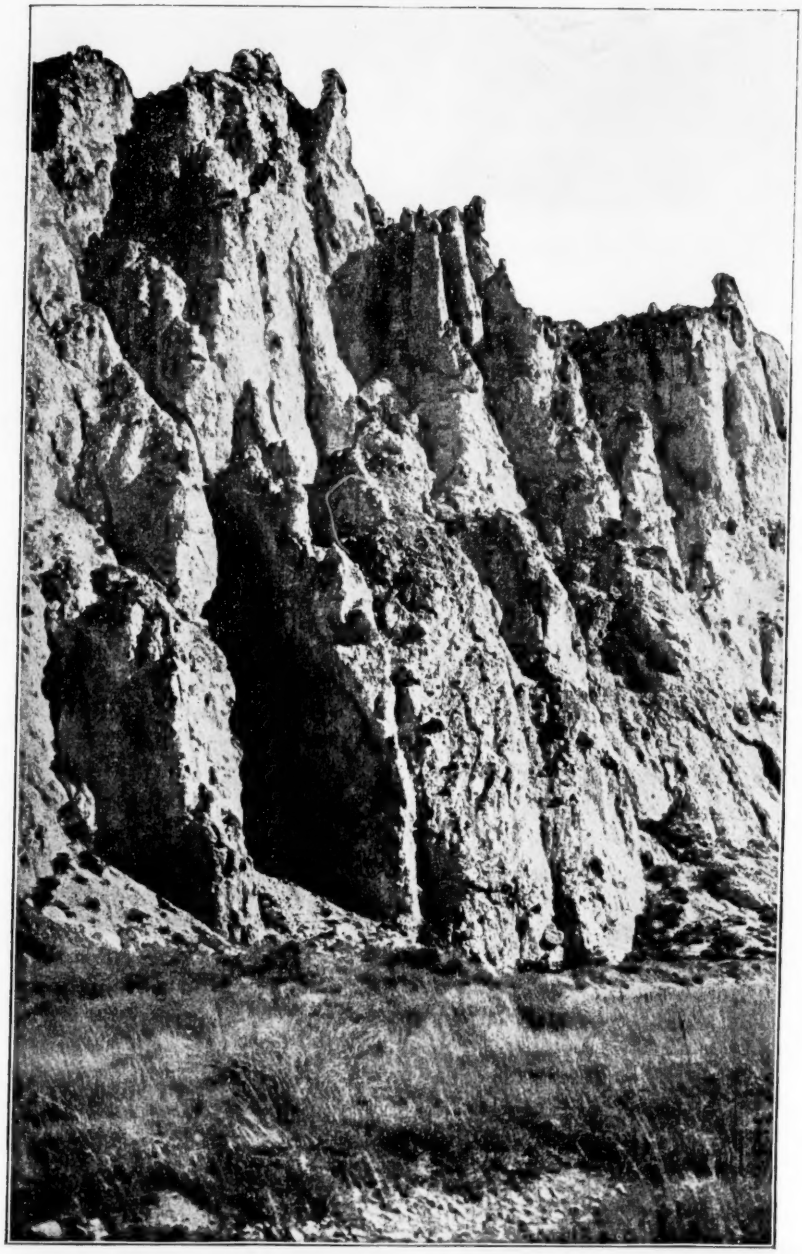
Other features to be noticed are the broad, deep, transverse valleys that cross Patagonia from west to east and form the chief drainage systems. These are all true valleys of erosion, and along their bot-

toms in most cases still flow the streams by which they have been eroded; though in some instances, like the Desire and Coy rivers, there are now only intermittent streams, while in the valley of San Julian no stream at present ever flows, the waters of the original stream having been captured long since at a distance of about 100 miles from the coast by a northern tributary of the Santa Cruz. The latter, considering the volume of its waters, is much the most important of all the rivers of the plains of southern Patagonia.

Another feature characteristic of these plains is the series of escarpments, often several hundred feet in height, that terminate a succession of terraces, encountered at varying elevations as one proceeds from the coast inland westward toward the Andes, or also in crossing from north to south any of the great transverse valleys. Such escarpments have a general trend somewhat parallel with that of the present coast line, but extend inland for many miles along either side of the valleys of all the more important watercourses, as do also the present bluffs of the sea. They are perhaps remnants of bluffs formed along the coast at different stages during the former depression and late elevation of the land, which would appear to have been intermittent and of which we have exhibited in the present bluffs of the sea the last stage. Between each successive escarpment a narrow, level plain extends, gradually increasing in altitude to the westward.

In many places over the plains the sedimentary rocks are covered with sheets of lava, which have usually had their origin in local dikes or volcanoes. Many of the latter rise high above the surrounding plain as imposing landmarks, serving alike to guide the traveler and lend variety to a rather monotonous landscape. These lava fields are most abundant over the central interior region, midway between the Andes and the coast, where they cover thousands of square miles. In some instances they present a broad level surface of almost illimitable expanse, covered with highly vesicular scoriæ, while at other times the surface over large areas is carved into a confusing labyrinth of deep, almost inaccessible, cañons. In either case they present a most serious obstacle to the traveler.

While these lava beds are most frequent over the central interior region, there is an important outlying area near the coast between the mouth of the Gallegos River and the eastern entrance to the Strait of Magellan, with several extinct volcanoes and resulting lava streams, which appear to have been ejected at a comparatively



BASALTIC WALL IN CAÑON OF A TRIBUTARY OF ARROYO GIO — SHOWING FACE DEEPLY DISSECTED BY NARROW, PERPENDICULAR CHASMS

From a photograph by J. B. Hatcher

BASALTIC PINNACLES, PLAINS OF PATAGONIA

From a photograph by J. B. Hatcher

recent date. In some few instances the lavas of the great interior region extend westward quite to the base of the Andes, but as a rule the surface of the plain for a distance of some 30 to 40 miles eastward from the base of the mountains is free from lava. It has either never existed there or has been entirely swept away or covered over by glacial detritus, as has been observed in some few instances.

That region lying between the western border of the lava beds and the foothills of the Andes is by far the most fertile of the Patagonian plains. Its surface, covered to a considerable depth with glacial deposits, presents a series of ranges of low, rounded hills, left as terminal moraines by the receding glaciers. Such ranges of hills have a trend parallel with the base of the mountains, and are usually separated by broad stretches of meadow land, with numerous small glacial lakes, either occupying slight depressions in the meadows or, as more frequently seen, embraced by the low, rounded hillocks of the terminal moraines. These conditions are especially characteristic in this region over the bottoms and slopes of the great transverse valleys, but they extend also in many places out over the surface of the higher pampas.

The rolling surface of this western plains region, abounding in wide pasture lands dotted over with sparkling lakes of pure, sweet water, presents a pleasing contrast to the semi-arid region near the coast, and affords a welcome relief to the traveler after a journey across the black, absolutely barren lava beds of the central plains. Its modest, unobtrusive beauty but emphasizes the grander scenery beyond, indications of which already appear in the distant ranges of the Andes, whose summits, buried deep in fields of snow and ice, are seen brilliantly white against the intensely black background formed by the storm-clouds of the western sky.

Entering the confines of the Andes, numerous rivers, deep rocky cañons, broad open lakes of beautiful clear water, fed by glaciers that descend from the snow-fields at the summits, and all the other features characteristic of an intensely rugged, mountainous region, thrust themselves upon the attention and excite the wonder and admiration of the traveler.

The country lying along and within the foothills of the Andes is in many respects the most interesting region in Patagonia, whether considered geographically or geologically. Taking advantage of any of the numerous valleys that extend westward from the western border of the Patagonian plains and penetrate not only the secondary but also the main range of the Andes, finally emptying into the

Pacific, many facts may be observed not only bearing directly upon the structural and historical geology of the Andes, but also throwing much light on the agencies which have contributed to the peculiar topography and determined the unique position of the continental watershed at present existing in southern South America.

I say unique, for I believe it has no parallel elsewhere. That its true position was quite unknown and entirely unsuspected, even at the beginning of the last decade, is clearly demonstrated by the unfortunate boundary dispute at present existing between Argentina and Chile. This dispute, which even within the last year seriously threatened the peaceful relations of these two South American republics, but is now happily approaching a peaceful settlement through friendly arbitration, arose from an attempt by joint commissions appointed by the two governments to establish and properly mark an international boundary line extending northward from the 52d parallel of south latitude. In their work of delimitation these joint commissions were to be guided by the text of a treaty entered into by the two governments in 1881, which stipulated that a line connecting the highest peaks of the Andes and dividing the waters of the Atlantic from the waters of the Pacific should constitute the international boundary line.

An attempt at a practical application of the conditions of this treaty soon demonstrated its impossibility and developed the fact, previously unsuspected, that the continental watershed throughout the entire extent of Patagonia, excepting only a small area about the source of the Santa Cruz River, was not formed by the main range of the Cordilleras but lay far to the eastward and in many instances extended even beyond the lowermost foothills of the mountains. It was clearly impossible, however good the intentions of the respective commissions might be, to comply with the conditions imposed upon them by a treaty based upon supposed geographical conditions which in reality do not exist, for no line can be drawn complying with the evident intentions and literal conditions of the treaty. But while the joint commissions did little toward tracing the boundary line between their respective domains, yet they have done much to increase our knowledge of the geography of the interior region of central Patagonia, which until the last two years remained almost entirely unknown.

The least frequented, and therefore least known, portion of Patagonia lies between the Santa Cruz River on the south and the 46th

parallel on the north, or approximately between the 46th and 50th parallels of south latitude. I visited this region in the summer of 1896 and 1897, accompanied by Mr O. A. Peterson. At that time neither the Argentine nor the Chilian commission had entered it, the labors of both having been confined to the more easily accessible districts to the north and south. A glance at any of the current maps will demonstrate how little indeed was then known of its interior. The few travelers who had previously visited it contented themselves with a journey up the Santa Cruz River to the lakes about its source, or at most with a trip over the old Indian trail leading from the mouth of the Santa Cruz River up the River Chico to within about 60 miles of the base of the Andes, and thence bearing almost due north over the plains to the head of the Senguer River and down the latter stream to the Chubut, never entering the mountains at any point on their journey. The whole was, at the time of my first visit, practically an entirely unexplored region, abounding in undiscovered and unnamed mountains, lakes, rivers, and glaciers, many of them of great size and exceeding beauty.

In connection with my work it became absolutely necessary to give names to some of the geographic features discovered, especially in my field-notes. Some of these names I afterwards published with sketch maps, showing their location, accompanying preliminary papers relating chiefly to the geology of the region. I endeavored as much as possible to avoid any attempt at a detailed geography of the region, realizing at the time the speedy completion of the infinitely more accurate and detailed geographic work of the Argentine Limit Commission, in charge of Dr F. P. Moreno, to whom more than to any other person we are indebted for all that is at present known of the geography of the interior of southern South America. I am pleased to see that my expectations have already been partially met by the publication in the *Geographical Journal* of a paper read by Dr Moreno before the Royal Geographical Society of London, accompanied by a sketch map giving most of the more important geographic features, and promising a larger map with more details in the near future.

I am not only gratified to see that the few names given by me have been adopted by Dr Moreno, but I am also confirmed as to the wisdom of my forbearance to enter the field of the professional geographer, which might very easily have resulted in a confusing synonymy of important geographic names.

Since Dr Moreno's paper is doubtless easily accessible, I shall not attempt a detailed description of this interesting region, but shall briefly discuss the factors which have contributed to produce the existing unusual drainage conditions. I am the more easily impelled to this course, since some of the theories advanced by Dr Moreno in explanation of certain features described by him appear to me untenable. At any rate, they are not supported by most of the observations made by myself during the past three years.

A study of the southern Andes at any point reveals the fact that they are composed of three distinct, parallel ranges, separated by two deep, narrow, longitudinal valleys. The middle of the three ranges is everywhere much higher than the two lateral ranges and may be reckoned as the principal range of the Andes. The western lateral range is at present partially submerged beneath the Pacific, but is still distinctly seen in the chain of islands extending all along the western coast. The western of the two longitudinal valleys is at present throughout the greater extent of Patagonia entirely submerged beneath the sea and is now represented by the narrow system of rather deep channels that separates the islands from the main land and offers an almost continuously navigable inland waterway extending from the southernmost point of the Brunswick Peninsula to the 42d parallel of south latitude, or throughout more than twelve degrees, a distance of over 700 miles.

The eastern lateral range of the Andes is seen in the foothills that rise somewhat abruptly from the eastern plains to a height in places of some 6,000 or 7,000 feet. They are composed almost entirely of Secondary and Tertiary sedimentary rocks, with occasional layers of intrusive basalts, the whole thrown up in a somewhat complicated system of folds of usually monoclines or anticlines terminating toward the west in a lofty escarpment, the crest of which overlooks the deep, narrow, and irregular, eastern longitudinal valley that separates the eastern lateral range from the central main range of the Andes. In this eastern longitudinal valley there is located a series of the most beautiful mountain lakes, extending northward in a somewhat broken chain from Lake Argentina, at the head of the Santa Cruz River, to the northern limits of Patagonia. At some distance to the south of Lake Argentina the bottom of the valley has not been sufficiently elevated and it is here occupied, not by freshwater lakes, but by numerous narrow arms of the Pacific, as seen in Last Hope Inlet, Obstruction Sound, Skyring and Otway waters, and Useless Bay, opposite Sandy Point, in the Strait of Magellan.

CAÑON OF RIO TARDE, FOOTHILLS OF ANDES

From a photograph by J. B. Hatcher

In many places important streams enter this great longitudinal valley from the eastern plains and discharge their waters into the lakes, which in turn are emptied into the Pacific through rivers intersecting the main range of the Andes. This is true of all the lakes of this region, with the one noted exception of Lake Argentina and its affluents. The upper courses of the great transverse valleys of Patagonia are always directly opposite some of the larger of these tributary valleys, so that at such places the continental divide is exceedingly low and inconspicuous. This condition, together with certain glacial phenomena, has led Dr Moreno to advance the theory that formerly all the lakes now found in the eastern longitudinal valley discharged their waters into the Atlantic, and that their diversion to the Pacific has been due to the damming of their eastern outlets with glacial drift.

A careful examination of all the facts does not, I think, justify such an assumption. I have examined with considerable care several of the low continental divides about the eastern extremities of some of these lakes, and have never found the original rocks there covered to any considerable depth with glacial detritus. The great terminal moraines left by the former ice-cap could always be seen crossing the transverse valleys some distance to the eastward of the continental divide, where I have observed them to have a thickness of more than 300 feet, as displayed in the bluffs of some of the streams which have cut their way through these moraines in their course to the Atlantic.

A more plausible explanation, it appears to me, is afforded by a consideration of the features at present existing throughout Patagonia and Tierra del Fuego in connection with a proper understanding of the relative land and sea areas that existed there during late Tertiary times, with an appreciation of the greater elevation which has taken place over northern than over southern Patagonia in recent times.

From the present distribution of the rocks forming the marine Patagonian beds we know that during Middle Tertiary times the entire southern extremity of the continent excepting the higher peaks of the Andes was submerged beneath a shallow sea. That this sea was nowhere very deep is shown by the character of the fossils, which are everywhere extremely abundant, and all belong to shallow water and littoral forms. The accumulation of the 900 feet of rocks now forming the Patagonian beds, containing throughout the fossil remains of characteristic shallow-water forms, can only be explained by assuming that this region was undergoing a subsidence sufficiently gradual to

just keep pace with the sedimentation going on over the bottom of the sea. After a time the rate of subsidence became less rapid or ceased entirely, and the shallow sea was gradually converted into a series of estuaries, lakes, and dry lands, in and over which were deposited the Santa Cruz beds of lacustrine and æolian origin. For a long period, extending over late Miocene and early Pliocene times, this region was elevated above the sea. During this long period of late Tertiary elevation the surface of the land was subjected to erosion, and the courses of all the more important valleys and drainage systems now existing were then determined. Toward the close of the Pliocene this entire region was again submerged beneath the sea for a short period, but sufficient for the deposition of the marine Cape Fairweather beds. During this second period of submergence the Andes would appear as a long archipelago of high mountainous islands.

At the close of the Pliocene there began over this region a process of elevation, which, as has been shown, was much more considerable toward the north than in the south. This difference in the amount of elevation accomplished in the northern and southern regions has determined the presence of the series of fresh-water lakes now found in the north in the same relative positions that are occupied farther south by the fiords and inlets from the Pacific. I have obtained absolute proof that this elevation in the north along the Andes has not been less than 5,000 feet, and that it has been much greater in the north than in the south and far greater along the Andes than over the plains.

As this elevation proceeded, each of the transverse valleys, which, as we have already remarked, had their origin previous to the last submergence, would appear successively first as straits connecting the two oceans, and next as valleys, with deep bays along the coast. The Strait of Magellan is the last or most southerly of these great transverse valleys, and still exists as a strait connecting the two oceans.

Turning now to the eastern longitudinal valley, it will be seen that as the elevation progressed it would at first be broken up into a series of fiords and inlets toward the north still communicating with the Pacific through the deeper channels intersecting the main range of the Andes. In time such communications would be severed and the heads and arms of the fiords would be left as lakes to discharge their waters into the Pacific by the last and deepest of the connecting channels. We have thus represented between the Strait of Magellan and

Lake Argentina every stage in the development of the present lake systems of the southern Andes.

A glance at one of Fitzroy's charts of the Magellan Strait instantly reveals the fact that it is much deeper in its western than in its eastern course. In fact, it is extremely shallow throughout its entire course from Useless Bay eastward to Cape Virgin, and only a comparatively slight elevation would here suffice to bring its bottom above sea-level and convert it into a valley connecting Tierra del Fuego with the mainland, and changing Useless Bay first into a fiord, and later into a lake as the elevation increased, sending its waters to the Pacific by way of the much deeper western channels of the straits.

The same conditions that exist today in the Strait of Magellan have existed at some previous time over all the great transverse valleys of Patagonia, and an elevation similar to that which has taken place more to the northward would produce conditions along the course of this strait identical with those now existing farther north. So also an elevation of the region south of Lake Argentina similar to that which has taken place north of this lake would convert Last Hope Inlet, Obstruction Sound, Skyring Water, and Otway Water from marine fiords connecting directly with the Pacific into a series of fresh-water lakes discharging their waters into the same ocean.

At present Otway Water is separated from Cabeza del Mar, a small bay extending inland from the eastern extension of the Magellan Strait, by a narrow neck of land only eight miles in width, and with a maximum altitude of perhaps less than 100 feet. Notwithstanding this low altitude, the low bluffs extending along the heads of both of these bays are largely composed of sedimentary rocks covered over with only a thin layer of glacial detritus, proving conclusively that the former connection that doubtless existed between these two bodies of water has been broken not by a damming up by glacial materials, but by an elevation sufficient to bring the sedimentary rocks at the bottom above the water level.

From the observations and conditions already referred to, and many other facts bearing directly upon these questions, I believe that the longitudinal valleys separating the main range from the two lateral ranges of the Andes, and also the great transverse valleys crossing Patagonia from east to west, had their origin previous to the last submergence, which took place over this region in late Pliocene times and continued only for a relatively short period. This submergence was greater over the western than over the eastern Andes, thus ren-

dering the western channels much deeper than the eastern. Toward the close of the Pliocene there began over this region a process of elevation, which, though general over the entire region, was greatest along a line approximating that of the axis of the eastern lateral range of the Andes, and was also greater over northern than over southern Patagonia. As the elevation proceeded the general surface of the land would be brought above water level, while the longitudinal and transverse valleys would remain submerged and appear respectively as channels from the Pacific and as straits connecting the two oceans. This condition may be termed the first stage in the process of elevation and is now seen in the Magellan Strait.

After a time a second stage would be reached, in which the transverse valleys would no longer appear as straits, but as land valleys, while the channel of the eastern longitudinal valley would be broken up into a series of fiords extending inland from the continuous channels of the deeper western longitudinal valley. This second stage is now seen in the region lying between the Strait of Magellan on the south and Lake Argentina on the north.

A third stage appears when the amount of elevation accomplished is sufficient to sever the connection existing between the east and west longitudinal valleys and reduce the fiords entering the eastern valley to a series of lakes discharging their waters by rivers into the channels of the western valley, still submerged beneath the sea. This third stage is seen in the region north of Lake Argentina, while a fourth stage, in which the bottom of the western longitudinal valley is brought above water level, appears in extreme northern Patagonia and the region to the northward, where it embraces the principal agricultural lands of Chile.

KITE WORK OF THE WEATHER BUREAU*

By H. C. Frankenfield,

U. S. Weather Bureau

As early as the year 1895, Prof. Willis L. Moore, Chief of the U. S. Weather Bureau, determined to undertake at the earliest practicable moment a study of the meteorological conditions existing in the free air over the United States, the data to be obtained from automatically

recording instruments attached to kites. Independent observations at single stations had been made previously by private individuals, notably those under the direction of Mr A. L. Rotch at Blue Hill Observatory, Mass.; but observations from a single station, while extremely valuable in themselves, are useless when comparative results are sought. It was the hope of the Chief of the Weather Bureau in establishing a chain of kite stations that it would be possible to construct daily synchronous charts of pressure, temperature, and wind velocity from the data thus obtained for different elevations up to at least 5,000 feet, and that from a study of these charts a marked advance could be made in the present system of weather forecasting.

An immense amount of time, labor, and experimentation was necessary before the kite apparatus could be brought to a high state of efficiency, the observers properly instructed, and the stations established, and it was not until the spring of the year 1898 that the work was fairly launched. In all seventeen stations were established, mostly in the great river valleys and the Upper Lake region.

The standard kite used was constructed largely after the Hargrave model, with various improvements suggested by actual trial and experiment. At some stations the kite contained 68 square feet of surface, at others a smaller kite of 45 square feet was used, and at still others a slightly larger one of 72 square feet of surface was occasionally used.

The meteorograph, an instrument for recording automatically the pressure, temperature, and relative humidity of the air, was devised by Prof. C. F. Marvin of the Weather Bureau. The mechanisms were inclosed in a light aluminum case, the whole being suspended within the framework of the kite.

It was soon discovered that the hope of a daily synchronous chart of the conditions existing at high altitudes could not be realized. On many days ascensions were impossible, owing to the absence of sufficient wind to sustain the kites. Neither could they be flown in stormy weather. There were made only 46 per cent of the total number of ascensions which would have been possible had wind and weather conditions been favorable. The percentage varied from 75 at Dodge City, Kans., to 12 at Knoxville, Tenn. When by chance ascensions were made at a majority of the stations on any one day, varying wind conditions necessitated their being made at different hours, thereby

*Summarized from Vertical Gradients of Temperature, Pressure, and Wind Direction: Weather Bureau Bulletin F, U. S. Department of Agriculture.

destroying the synchronism of the observations, without which aërial observations would be of little assistance to the forecaster in his work.

However disappointing the results obtained may have been when viewed from the standpoint of weather forecasting, they were very far from being so from another. An immense amount of data was obtained from the 1,217 ascensions and 3,835 observations, particularly in reference to temperature variations with increase of altitude, and it is believed that our previous knowledge of this subject has been materially increased.

Briefly summarized, the results of the observations were as follows:

There were considered in all 3,835 observations, of which 603 were at 1,000 feet elevation, 906 at 1,500 feet, 928 at 2,000 feet, 746 at 3,000 feet, 423 at 4,000 feet, 182 at 5,000 feet, 38 at 6,000 feet, 7 at 7,000 feet, and 2 at 8,000 feet. Of the two at 8,000 feet, one was obtained at Washington, D. C., and the other at Dodge City, Kans. In the Mississippi Basin, except on the slope of the Rocky Mountains, high ascensions were impossible, as the average wind velocity was but six miles or less per hour.

The mean rate of diminution of temperature, with increase of altitude, was found to be 5 degrees for each 1,000 feet, or only 0.4 degree less than the true adiabatic rate. This is strictly a mean value, obtained from observations taken at all elevations from 1,000 to 8,000 feet, and under varying conditions of weather and at different hours.

The largest gradient, 7.4 degrees per 1,000 feet, was found up to 1,000 feet, and thence up to 5,000 feet there was a steady decrease to 3.8 degrees, the rate of decrease varying inversely with the altitude. Above 5,000 feet there was a tendency toward a slow rise in the gradient, but the lack of a sufficient number of observations above 6,000 feet prevents a positive assertion to this effect. The morning gradients were also greatest up to 1,000 feet, and least up to 5,000 feet, and the rate of decrease was about the same as that of the mean, the curves showing a very close agreement in this respect. The average morning gradient was 4.8 degrees per 1,000 feet.

The afternoon gradients were larger, but not decidedly so, the average value being 5.8 degrees per 1,000 feet. The greatest rate of decrease is still found at 1,000 feet, and the least up to 5,000 feet, if the few observations at 7,000 feet are not given equal weight.

The morning, afternoon, and mean gradients for the different elevations from 1,000 to 8,000 feet are given in the following table:

Decrease of Temperature for Each Respective 1,000 Feet of Altitude

	1,000 feet.	1,500 feet.	2,000 feet.	3,000 feet.	4,000 feet.	5,000 feet.	6,000 feet.	7,000 feet.	8,000 feet.	Mean.
	°	°	°	°	°	°	°	°	°	°
Morning	7.2	5.5	4.8	4.0	3.7	3.7	3.9	3.4	3.0	4.8
Afternoon	7.5	6.4	6.0	5.5	4.9	4.3	4.5	3.5	4.9	5.8
Mean	7.4	5.8	5.2	4.4	4.0	3.8	4.1	3.4	4.0	5.0

A grouping of the stations according to their geographical locations disclosed the fact that the mean rate of temperature decrease with increase of altitude was much greater in the central Mississippi watershed than in the Upper Lake region, the central West, or the extreme East as represented by the single station at Washington. In the afternoon, however, the differences were very small, the maximum being only 0.7 degree per thousand feet.

The morning, afternoon, and mean results for the various districts are shown in the following table:

Gradient per Thousand Feet

District.	Morning.	Afternoon.	Mean.
	°	°	°
Atlantic Coast	3.4	6.0	3.6
Central Mississippi watershed	5.8	6.1	5.8
Upper Lake region	4.5	5.4	4.6
Central West	4.3	5.6	4.7

It will be at once remarked that there is a very close agreement between the means for the Upper Lake region, those for the central West, and the grand mean of 5.0 degrees, as well as a marked deficiency on the Atlantic Coast, amounting to 1.4 degrees per thousand feet.

Negative gradients of temperature, or "inversions," were quite frequent during the morning hours at a number of the stations, and they, of course, bear a direct relation to the amount of cloudiness and the velocity of the wind. At Washington on June 21, 1898, the temperature at an elevation of 866 feet was 14 degrees higher than at the surface, and 10 degrees higher at 1,700 feet. At Dodge City, Kans., on October 23, 1898, there was an inversion of more than 11 degrees at an altitude of over 5,000 feet. As a rule, however, the amount of inversion was less at Dodge City than at Washington on account of the prevailing higher winds at the former place.

The central fact of importance which the study of inversions developed was that they were most pronounced with the radiation of relatively warm southeast to southwest winds, the marked cold at the surface and the higher warm air presenting a marked contrast, which was not so apparent when the upper air blew from a colder northerly direction.

Inversions were sometimes caused by cloud formation in the early morning. Below the clouds there would be little or no temperature change, while above there would be an increase on account of the direct action of the sun's rays. On October 1, 1898, a marked case of this character occurred at Dodge City, there being a rise in temperature of 11.5 degrees within a few minutes after the kite emerged from the upper surface of the clouds.

The most remarkable instances of inversion were found at Duluth, Minn. Nearly one-half of them occurred in the late morning and early afternoon, during cloudy weather, and were due to the easterly surface winds from Lake Superior, the warming effect of these winds being sensible at times to the height of nearly 6,000 feet. During these inversions the direction of the upper air current would be almost or entirely diametrically opposite to that at the surface. On June 3, 1898, there was an inversion of 2 degrees at an elevation of 5,372 feet, and on September 20, 1898, one of 1 degree at an elevation of 5,714 feet.

The effect of the presence of clouds upon the temperature gradient was quite uniform, though not at all times decided. In a great majority of instances there was a decrease in the rate of temperature fall, frequently amounting to a complete arrest, and less frequently to an inversion. After the kite emerged from the clouds the rate of temperature change would be diminished.

In a number of instances the clouds appeared to have no effect whatever, and in a few rare ones there was a fall in the temperature as the kite came in contact with the clouds.

As a rule, the temperature gradients were greater in clear than in cloudy weather, although exceptions were quite numerous.

The relative humidities at and above the surface of the earth differed but little, and, except at 2,000 and 8,000 feet, the upper air percentages were the lower. The mean results obtained from all the observations were 60 per cent at the surface and 58 per cent above, a difference of 2 per cent. There were, however, some marked differences at individual stations, viz., Washington, 14 per cent; Omaha,

Nebr., 29 per cent; Springfield, Ill., 21 per cent, and Fort Smith, Ark., 12 per cent, the surface humidity being the higher, except at Fort Smith. At thirteen out of the entire seventeen stations the difference did not exceed 10 per cent, and at nine stations it was 5 per cent or less.

For obvious reasons, as the altitude increased, the relative humidity decreased whenever the winds were from north to west, particularly from the northwest, and increased with winds from east to south, particularly with those from the east. When the kite was in or near clouds, the humidity would almost invariably rise, falling again when the kite was freed from cloud influence.

Vapor pressures were expressed in percentages obtained by the formula $\frac{p}{p^o}$, "p" representing the vapor pressure at any given altitude and "p^o" that observed simultaneously at the earth's surface. The mean thus obtained was 59 per cent, and there was a steady, though by no means uniform, decrease with increase of altitude. The percentage at 1,500 feet was 82 and at 8,000 feet 44. The decrease was most rapid between 2,000 and 5,000 feet, where it averaged 9 per cent for each 1,000 feet. The lowest percentage, 52, was found at Omaha, Nebr., and the highest, 77, at Pierre, S. Dak.

A comparative statement of kite, balloon, and mountain observations is given below. In determining these results the records of 1,123 kite ascensions were used. There were 4 balloon ascensions by Hammon and 2 by Hazen. It is not known how many observations were made by Hann.

Diminution of Vapor Pressure with Altitude

Value of $\frac{p}{p^o}$ for each respective 1,000 feet of altitude

Character of observations.	1,500 feet.	2,000 feet.	3,000 feet.	4,000 feet.	5,000 feet.	6,000 feet.	7,000 feet.	8,000 feet.	Mean feet.
Kite	0.82	0.78	0.70	0.61	0.52	0.49	0.39	0.44	0.59
Balloon (Hammon)	0.96	0.96	0.87	0.68	0.44	0.59	.....	.....	0.75
Balloon (Hazen)	0.89	0.83	0.80	0.78	0.67	0.46	0.44	.....	0.70
Balloon (Hann)	0.84	0.80	0.66	0.61	0.60	0.54	0.41	0.37	0.60
Mountain (Hann)	0.83	0.81	0.80	0.66	0.61	0.58	0.55	0.47	0.66

Differences in wind direction were indicated by the changes in the azimuths of the kites. These showed that, as an almost unvarying rule, the general directions above and at the surface were practi-

cally the same, the differences being confined to a deflection toward the right at the kite. This deflection frequently increased with the altitude, but rarely exceeded 90 degrees. In some few instances the kite was deflected toward the left, but not to any great extent. When the deflection was toward the left, the wind velocity decreased with increase of altitude, as shown by the diminished pull on the kite wire. As a matter of interesting coincidence, and without intention of endeavoring to establish a direct relation of cause and effect between the two, it may also be stated that these deflections toward the left were quite frequently followed by thunderstorms within a few hours.

At Duluth, Minn., there were occasionally wide divergencies of the kite toward the left, due to the northeast wind from Lake Superior. This northeast wind was very often purely local, attributable entirely to the influence of the lake, and corresponding in a minor way to the sea breezes of the ocean shores. It developed upon investigation that these local currents were sometimes not more than 700 or 800 feet in depth, and rarely more than 2,000 feet.

Hammon * and McAdie recorded a somewhat similar experience with the westerly surface winds at San Francisco during their kite experiments in 1896, and in his paper on the subject Mr Hammon concluded that the strong westerly surface wind which prevails on the Pacific Coast nearly every afternoon has a depth of only 800 to 2,500 feet.

An extension of the aërial observations to other seacoasts would doubtless prove conclusively that the diurnal sea breezes are extremely shallow.

After November, 1898, all kite stations were closed except that at Pierre, S. Dak., where ascensions were made whenever possible during the year 1899, and still continue. No extended study of the observations made during this time has as yet been made, but a cursory examination of the winter temperature records discloses a condition of affairs radically different from that which prevails during the remaining seasons of the year. The inversions are very frequent and decidedly marked. Indeed they are so persistent during the colder weather as to lead to the inevitable conclusion that during a cold wave the belt of cold air is not much over one mile in height, and often but little over half a mile.

On several days it was also noticed that there were at least three

* Experiments with Kites at San Francisco, Cal., by W. H. Hammon, forecast official. Monthly Weather Review, August, 1896.

distinct air strata within very narrow vertical limits: a lower cold one extending upward about 1,500 feet; a warmer one extending to between 2,500 and 3,000 feet, and then a second cold one of unknown extent.

The entire subject of aërial investigation offers a very attractive field to the student. The work has just begun, and future investigators must certainly bring to light many truths, now concealed, which will prove of the utmost interest and value to themselves, the cause of science, and the world at large.

PRACTICAL EXERCISES IN GEOGRAPHY

By W. M. Davis,

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The graduate of a high-school course in physical geography cannot be expected to have reached the stage of independent and original investigation in new fields unless he possesses unusual mental capacity, but he ought certainly to be able to recognize the outdoor occurrence of things similar to those that he has studied in school. This would be difficult if he had studied only a book, even if its text gave good presentation of names, definitions, descriptions, and explanations, supplemented by pictures and maps. It is probably for this reason that we find today an essential unanimity regarding the addition of practical exercises in some form to the lessons in physical geography based on a text. The reports made by the several committees of the National Educational Association—the Committee of Ten (1893), Committee of Fifteen (189–), and the Committee on College Entrance Requirements (1899)—all emphasize the importance of observational exercises in field and laboratory; and many progressive schools in which courses of high-school grade in physical geography are given today are doing their best to solve the difficult problems that arise when the attempt is made to put these recommendations into practice.

Attitude of Teachers.—The advantages that come from well-planned field and laboratory exercises in physical geography are so great that the difficulties in their way must be overcome in one way or another. Fortunately there is today no more effective aid toward this end than the desire of the teachers themselves to gain it. This is mani-

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fested in many healthy ways. There is the frank recognition by the teachers of deficiencies in their preparation; there are strong efforts to make up the deficiencies by outside study or by attending summer courses in which laboratory work and field excursions are included, and I may say that no classes that I have ever had have shown a better spirit than those composed chiefly of school teachers in the summer vacations. Superintendents and principals manifest the same interest in progress by devoting specially assigned space in new school buildings to work of this kind, by making inquiry as to the necessary outfit, and by planning schedules in which hours for outdoor work have due consideration. Educational journals reflect the general interest in the practical aspects of geography by publishing a good number of articles that are devoted to this branch of the subject; the *Journal of School Geography*, for example, in the thirty numbers issued for 1897, 1898, and 1899, contains many articles bearing on field and laboratory methods, some of them being prepared by the editors in direct response to questions from the subscribers.

Relation of Practical Exercises to Text Book.—It is desirable that the practical work of a course on physical geography in the high school should be closely parallel with the book work, for the reason that the main outline of the subject is best presented definitely and specifically in printed form; but it must be recognized that many obstacles stand in the way of the easy attainment of this ideal. In the first place, exercises on certain subjects must be very deliberately carried on, requiring even a whole school year for their proper inductive development. These must either anticipate the high-school course or they must advance independently of the text in which their equivalent is stated in printed form. The study of the weather finds some of its best applications in observation of storms and other special conditions at the time of their occurrence. These must be taken up in the order of their happening, and reference must then be made forward or back to their systematic treatment. Our climate is such that the open field season comes in the fall and spring, while many topics under the important heading of land forms will often be taught from the book in the winter, when field work is difficult or impossible. Indeed, even in fall and spring, an excursion, well planned to illustrate the text in hand at the moment, may have to be postponed on account of bad weather, thus disorganizing our best intentions. It is true that laboratory work may often supplement or replace field work, but not sufficiently to smooth out all the difficulties noted

above. Simple parallelism between text and practical exercises is therefore out of the question, and we must be content if some effective correlation between the two is gained instead. In order to give specific indication of the character of various practical exercises and of the correlations that may be established between such exercises and book work, let me open the subject with some examples appropriate to the study of that interesting chapter of physical geography which is often given a forbidding appearance under the name of "mathematical geography."

The Earth as a Globe.—It is seldom that justice is done to the opportunity of practical work under the heading of the earth as a globe. The difficulties that stand in the way of various observational exercises may certainly be overcome if their accomplishment rather than the maintenance of a set order of school periods is made the object in view. Many series of observations that cannot and need not be made by a whole class may be made by scholars singly or in pairs; the avoidance of such exercises, because of the disorder that they may create, does not speak well for the discipline or for the spirit of the school. Several of these exercises are best performed under the name of nature study in lower grades than the high school; they are mentioned here because if, as is too often the case, they have not been performed in their proper place they should be given place in the high school; but it is manifest that such a plan disarranges the high-school course in physical geography and retards the attainment of the grade that it deserves.

Shape of the Earth.—The only observational proof of the globular shape of the earth that is within the reach of young scholars is offered at the time of an eclipse of the moon. Such an opportunity should not be lost sight of. The edge of the earth's shadow always having a curved outline, the earth must be round, as Aristotle perceived four centuries before the Christian era. The time-honored proof afforded by the gradual disappearance of ships at sea is available only at the sea-shore; it is interesting to note that this proof was first mentioned by Strabo. Accepting the globular form as a fact, the horizon plane, touching the earth's surface at the observer's station, extends indefinitely on all sides; the visible sky lying above, the invisible sky lying below the plane. As long as the earth is thought of as a large body in comparison to the dimensions of the sky vault, it will probably be more or less consciously believed that the smaller half of the sky is above and the larger part is below the horizon of an observer.

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But when the earth is stated to be very small in comparison to the distance to the stars, the two parts of the sky separated by a horizon plane will be recognized as equal. The horizon planes of observers at different points on the earth will cut the sky into different halves, as may be shown by the aid of a hand globe. The uneven border of the sky against hills should be called the sky-line, not the horizon. All this is as much astronomy as geography; but it is all essential to the clear understanding of matters that are constantly taught in geography, such as latitude and the seasons; no safe entrance into such matters can be made without careful attention to fundamental concepts.

The discovery, attributed to Eudoxus, that an observer, traveling north or south, sees that stars change their position with respect to his horizon, will be considered in connection with measures of the size of the earth further on.

The causes and consequences of the earth's shape are better presented in the text than in practical exercises. Among the consequences are the essentially uniform value of gravity at all points on the earth's surface, and the absence of immense ascents and descents that must occur on an earth of any other shape. The nearly globular form of the actual earth has been of enormous importance during long past ages in facilitating the migration of plants and animals from one region to another, and in recent centuries in permitting the migrations of mankind and the development of commerce.

Rotation.—The vague ideas in the minds of adults regarding the earth as a rotating globe suggest that no good ground was provided in their school days for a correct understanding of this fundamental problem. The problem pertains equally to geography and to astronomy; but as it should be encountered before these two subjects are differentiated, it is naturally classified under the first and more usual school subject. Very simple apparatus suffices. A pointer, pivoted at one end and sighted at the sun at different hours through the day, enables a young observer to gain a definite idea of the sun's (apparent) daily movement across the sky. (Actual sighting at the sun is not necessary; when the pointer is held so that its shadow is no larger than its cross-section, it is properly directed.) Record of successive observations may be made by setting up stakes so that their tops shall just touch the end of the pointer in the successive sights at the sun. On the following day the sun may be seen again in the earliest position observed on the first day, the period thus measured being a natural

unit of time which civilized nations divide into 24 hours. It is important to notice that the sun's return to its original position has not been accomplished by going backward, but by continuous motion as if in a circuit. The idea of rotation is thus clearly presented in spite of the fact that much of the sun's diurnal path is out of sight. It should not be understood that these observations give school children their first knowledge of the movement of the sun in the sky; that they have long known. But the vagueness of ordinary knowledge on this point is now advanced to well defined knowledge, and this is an important step.

Regularity in the movement of rotation is easily shown by making observations at regular intervals of one or two hours and noting that equal angles are moved over by the pointer, or that equal arcs are measured between the stake tops in equal time intervals. It is, I believe, well understood by teachers today that no preparatory study of formal geometry is needed as a basis for inspectional geometry of this kind. A little more advanced treatment is given by making observations at irregular periods, noting the time intervals between them, and proving by a continued proportion that angles and times bear a constant ratio. The angle of complete rotation (360°) will be found to bear the same ratio to the time of a complete rotation (24 hours) as that which obtains between partial angles and times; hence the movement of the sun while it is beneath the horizon must be at the same angular velocity as while it is within reach of observation above the horizon. Day-time observations of the old moon (about third quarter) and evening observations of stars at home may be used to extend the results gained from the observations of the sun. If the moon is studied, the teacher should be prepared to explain the questions that may rise if the difference in length of solar and lunar days is detected. The chief point to be determined by star observation is that a star must make a circuit of the sky in about 24 hours, because on the second evening it comes from the eastward to the position from which it departed with a westward motion the night before—an elementary matter truly, but one which is less clearly known to many civilized adults than it was to their barbarous ancestors.

Axis and Meridians.—As a result of these observations it is recognized that "something" must turn. Whether it is the earth or the sky that turns need not be decided at once, if the teacher has the patience to let this archaic problem really take possession of the

pupils' minds. In either case, the fact of turning demands an axis on which the turning shall take place, and if the pupils have any serious difficulty in discovering and stating the attitude of the axis the teacher may be sure that the difficulty lies chiefly in the form of her questions, for the problem is essentially easy to living boys and girls, however difficult it may seem when clothed in words to which they are not accustomed. When the "slanting" attitude of the axis of turning is clearly recognized, all problems of size, latitude, and longitude are greatly simplified. By whatever short-cut the teacher presents the conclusion that the earth and not the sky really turns, the axis must be conceived as passing through the earth's center, and as defining two significant points, the poles, where it "comes out." The discovery of the north pole of the sky near the North star (really more than two moon diameters from it toward the end of the Dipper handle) leads to a clearer understanding of the diurnal paths of the stars in smaller or larger circles.

The shadow cast by a vertical pole on level ground by the midday sun shows us the direction in which one must travel to reach the North Pole. The prolongation of this line around the earth gives a meridian circle. The meridians are standard lines of direction. The equator is the great circle that cuts all the meridians in halves, midway between the poles. A series of meridians drawn at equal distances apart at the equator divide the earth into equal areas, conveniently arranged for measuring the relative easting or westing of places. A small hand globe may be appealed to in this connection, but constant reference should be made to "outdoors" as a part of the real earth on whose surface the imaginary circles are to be traced. "There" on a hand globe is not so useful as "there," pointing out the window toward the equator. The latter may arouse a live sense of directions, always useful in self-orientation, whatever is one's path in life; the former may leave the subject an unreality.

Latitude.—The determination of local solar time and of magnetic variation may be introduced in this connection, but more important is the estimation of one's position on the earth's surface with respect to the pole and equator. No mention of the term "latitude" need be made till this question is solved. It may be solved even in the grammar school by means of the sun-circle, marked out by stake tops, as above described. First, some general considerations. To an observer at the pole the sun or the stars would travel around the sky once a day, in circles parallel to the horizon. The position of the

star circles remains fixed wherever the observer goes and however much his horizon changes from the position that it had at the pole. As the observer moves along any meridian toward the equator his horizon must progressively tilt from the position that it had at the pole; and the amount of tilting may be measured by the angle between the tilted horizon and any one of the star or sun circles. This is, in essence, the method of Eudoxus, already referred to. A third way from pole to equator the angle would be 30°; half way, 45°; two-thirds way, 60°; at the equator, 90°. The rotation of the earth is thus of great assistance in determining the relative positions of places. Bearing these principles in mind, let the sun-circle be determined and represented by a series of stakes in a school yard, as in figure 1. Stand about 30 feet to one side of the stakes, in such a posi-

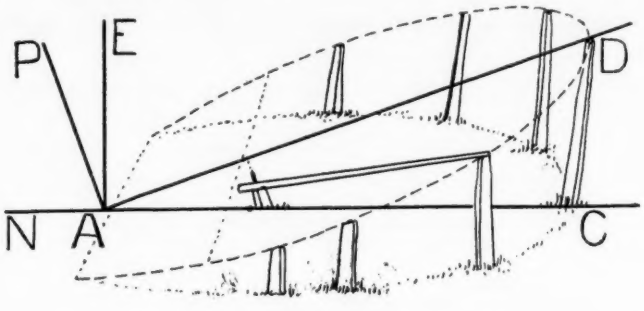

FIGURE 1

tion that the tops of all of them fall into a slanting, straight line when the observer's head is lowered to the height of the highest stake; estimate or measure the angle, CAD, by which the horizon is depressed beneath this slanting line*; and as the angle thus determined is to 90°, so is the distance from the pole (measured along a meridian from the pole to the observer) to the entire quadrant of the meridian from pole to equator. Latitude is counted from the equator toward the pole; it will therefore be the complement of the angle just measured. It should be noted that latitude may be thus determined at any time of year and without knowledge of the sun's angular distance from the sky equator (declination).

* The pivot does not lie in the plane of the sun-circle, and the slanting line does not measure the sun's noon altitude, except at the equinoxes. The noon altitude of the sun varies through the year, but the slanting line (the slant of the plane of the sun-circle) is constant through the year, whatever the declination of the sun. In all this method of determining latitude it is assumed that the motion of the sun in declination in a single day will not be detected by the rough methods of record here employed.

An interesting feature of this elementary method of latitude determination is its novelty to many teachers. It involves nothing that grammar-school pupils who have learned by seeing and thinking, not by recitation, cannot easily apprehend if they are gradually led up to it by a well graded flight of steps; the steps are not difficult and the flight is not long. The fear that they are so, on account of which many a teacher dreads to introduce fundamental work of this kind into her teaching, only goes to show the obscurity and confusion in which the chapter on so-called "mathematical geography" is often enveloped. Leave out this forbidding name, teach slowly on the basis of gradually accumulated observations, and the imagined difficulties will disappear.

The determination of latitude by the altitude of the Pole star should always be preceded by a proof that the star is close to the pole; but even then the sun-circle method is to be preferred as being possible in the daytime. The measurement of latitude involving the sun's declination should not be introduced until the movement of the sun in declination has been followed and its greatest northing and southing measured by a simple method given below.

Size of the Earth.—Nothing has yet been said of the size of the earth. Observations at a single station will not serve to measure the size, but the essence of the method of measurement may be usefully imitated, and, by correspondence between two schools, actual measurement may be made, much to the edification of the pupils. The relations of the local horizon to the plane of the sun-circle, as involved in the measurement of latitude, enables the scholar to "see," if not to demonstrate, that an angle of one degree must separate the local horizons of two stations on the same meridian, whose latitude differs by one degree. Similarly, if observations of the sun's midday (meridian) altitude were made at two such stations on the same day the altitudes would differ by one degree. Then, measuring the distance along the meridian arc between the stations, a simple proportion gives the circumference of the meridian circle:

$$1° : 360° :: \text{length of arc} : \text{circumference}.$$

This imitates the method employed by Eratosthenes. Two parties of scholars stationed at the ends of a short meridian arc in a school yard or in an adjacent common may each determine the noon altitude of the sun and measure the distance between their stations in imitation of the genuine method of earth measurement, and they

may be convinced that if their observations were minutely accurate the size of the earth could be estimated from even so short an arc as that which they can pace during a recess interval. If a hill rises near the school the convexity of the hill may be taken to imitate the rotundity of a little earth. Two parties stationed out of sight of each other on the north and south slopes of the hill, and on a north and south line, may determine the sun's noon altitude with reference to the slopes of the hill (which imitate the curved, level surface of a little earth), and then measuring the arc between their stations, the size of a small earth to which such a hill would fit may be determined. In the absence of a hill, a useful substitute may be provided in a school yard by placing two tables or boxes in a north and south line fifty or a hundred feet apart, tilting their upper surfaces away from each other, and then proceeding on the pretense that the table surfaces are parts of a little earth, whose convex meridian may be indicated by the tops of a row of stakes between them. The curved surface of a globe in a school-room may be used to explain the geometry here involved, but outdoor work should not be altogether replaced by such indoor substitutes. Nothing can so well give the sense of the real great earth as outdoor observations.

Two schools can profitably coöperate to measure the size of the earth. On a certain day agreed upon beforehand the midday altitude of the sun is determined at each school. The length of the meridian arc between the latitude circles of the two schools may then be measured on a good map and the proportion of Eratosthenes again employed to find the unknown quantity. If each school determines its own latitude, the difference of latitudes replaces the difference of the sun's midday altitude on a given day, and then no agreement as to the day of observation is necessary. Why is it that nature study of this kind, so appropriate to the inhabitants of a rotating globe, is not introduced in our lower schools? Is it because of the supposed difficulty or the actual simplicity of the necessary observations; on account of a recognition or a neglect of their value; on account of a confidence in the innate ability of young scholars or a mistrust of their powers; or on account of preparation or lack of preparation on the part of the teachers? To the best of my belief, this is merely one of the many cases in which the real mental activity of school children is benumbed by substituting recitations of words for live performance.

Longitude.—Difference of longitude (introduced under any name that is suggested by the pupils when talking freely of the relative positions of places on a rotating globe—the technical name to come in later) can be determined between two schools in any one of the three historical methods. As Strabo employed an eclipse of the moon to determine the relative easting or westing of certain points bordering the Mediterranean, so school children in different parts of the country may employ a lunar eclipse today to determine the relative positions of the meridians on which their homes are situated, previously determining their local solar time, and subsequently comparing the recorded time of any phase of the eclipse by correspondence. As governmental parties a hundred years ago made chronometer expeditions between neighboring national capitals, so school children may today send a watch from one school to another by express, and thus make a very good determination of difference of longitude. As modern observers employ the telegraph for time comparisons, even if separated by the whole breadth of a continent or of an ocean, so school children may today delegate some of their number to go to a telegraph office and send "time signals" from their watch (previously set to local solar time by their own observations) to an expectant party at the other end of the line. The two parties may have to wait half an hour or so to get the line "clear," but such a trifling delay should be no obstacle to success; and even such delay may be avoided if a long-distance telephone is used; then the time signals may be counted aloud by one party and directly heard by the other. Surely it is not the lack of capacity on the part of the pupils; it is not the expense involved; it is not the difficulty or the uselessness of the work that keeps such practical experiments as these out of our schools. What is the real difficulty in the way of their introduction?

Indoor Exercises.—Practical exercises of another kind on the earth as a globe may be performed indoors.* A meridian section of the earth as a sphere and as a spheroid may be drawn to scale in order to show how vanishingly insignificant the polar flattening really is. Geographically, its value is negligible in a high-school course, however important and interesting it is in astronomy and however valuable it is historically as a proof of the earth's rotation. The height of the highest mountains, the depth of the deepest oceans, the mean altitude of continents, the mean depth of sea floors, and the rate of in-

*Several of these exercises have been suggested to me by Mr W. H. Snyder, of Worcester Academy.

crease of interior temperatures may all be shown on this earth section. Comparisons of local and general distances and heights may be made by drawing them to scale.

Several methods of map projection may be illustrated. First the necessity for projection should be shown by the impossibility of smoothly laying a paper, cut to match a continental outline, upon the surface of a globe. The mercator (or stove pipe and cannon ball), the conical, and the gnomonic projections may be easily constructed; their difficulties may be magnified if clothed in mathematical language or minified if talked about familiarly. After a network of meridians and latitude circles is drawn out a continental outline may be platted from a table giving the latitudes and longitudes of a number of points on the coast line. Greenland and South America on Mercator projection, Greenland on Mercator and conical projection, the margin of the unexplored areas in the Arctic and Antarctic regions on gnomonic projections all afford good practice for platting. Comparison of distances on globes and on maps serves to detect the distortion characteristic of each kind of projection. A great-circle sailing course between San Francisco and Yokohama, as determined on a globe, may be transferred to any projection by the latitude and longitude of a number of points on its path. The same may be tried on a polar gnomonic projection of the great southern ocean for a voyage from Cape Horn to Tasmania. The results in the two cases are interesting and instructive. From my own experience with school teachers in problems of this kind, it is necessary to conclude that geometry must, as a rule, have been very badly taught to them.

Terrestrial magnetism affords some interesting exercises, if time can be allowed to them. The local variation of the magnetic needle has already been determined. Charts published by the Coast Survey and elsewhere give, by means of lines of equal variation, the values of local variation at any desired point. Local values thus obtained may be copied off on the blackboard, and the pupils may then write in the values on a Mercator map of the world (of their own construction, if desired), or on an outline map of the United States. The values thus charted afford practice in drawing lines of equal variation. The accuracy of the work can be tested by comparing the results with the original chart. A variation on this exercise may be made by drawing arrows at various stations to represent the local direction of magnetic north. Extend the arrows, curving them, if necessary, so that they shall not cross each other; they will then represent magnetic me-

ridians. The north magnetic pole, in the neighborhood of Hudson Bay, may be thus discovered. The meaning of magnetic charts can hardly be made clear without performing exercises of this kind.

The point that deserves special emphasis with regard to all the exercises thus far described is not so much their importance, although all are important, but rather their practicability. If the shape and size of the earth, latitude and longitude, and terrestrial magnetism are taught at all, practical exercises should replace recited definitions as far as possible. In all stages of the work excellent practice in English composition is afforded by calling for written description of observations and for careful formulation of results.

The Atmosphere.—The study of the atmosphere suggests a great variety of practical exercises, many of which are now familiarly introduced in our schools. Local observations, without and with instruments, are made and discussed systematically. They are correlated with the larger phenomena of the weather maps, but the work in this direction often falls far short of its possible measure. In this connection I may refer to a recent book by my colleague, R. De C. Ward, entitled "Practical Exercises in Elementary Meteorology," in which the teacher and the pupil will find precise directions for the solution of a large number of problems that I am sure will be of great value in giving fuller appreciation of the treasures stored up in, but not always taken from, the daily weather maps. This guide book being now accessible, I need here refer only to certain problems that are associated with the seasons. Here, as under the earth as a globe, it is too commonly the practice to learn definitions, instead of developing a real knowledge of the subject by the study of gradually accumulated observations. The need of plenty of time, only to be secured by carrying on observations during one or two years, is nowhere better illustrated than in this chapter of the subject. It is impossible to compress the necessary observations into the short time during which a high-school course would be concerned with the atmosphere. Adequate attention to the subject can be obtained only when the work is distributed over a long period in the grammar school, associated either with geography or with nature study.

The Seasons.—The procession of phenomena observable in the annual succession of the seasons is observable in early school years. The observations here described are intended to connect the simplest seasonal phenomena with their causes, which are to be found in the revolution of the earth around the sun, and in the resultant northing

and southing of the sun (or its movement in declination, declination in the sky being the equivalent of geocentric * latitude on the earth).

The fact of seasonal change having been already recorded in a most elementary way, let a second record be made in connection with a search for the causes of change, as follows: At intervals of a fortnight or a month determine the midday altitude of the sun. At similar intervals determine the time, and if possible the compass direction, of sunrise and sunset.† Again, at similar intervals, have the scholars, or at least the brighter ones, note the star groups that appear in the east shortly after the time and opposite to the point of sunset. All the facts thus determined vary systematically and in correlation with one another. The discovery of their system of change and of the correlations in the system should, if possible, be reserved for the scholars. Their intelligence is only half developed if the discoveries that they can make are made for them. In such case it may be claimed that time is saved, and that the results reached are the same; but it should be seen, on the other hand, that the scholars lose much appreciation of the result if they do not find it for themselves, and that they will fail entirely to acquire the power and the habit of discovering if they have no practice in it. If American schools are developed on a truly democratic basis, as befits republican institutions, one of their chief values will be that they aid in giving every boy and

* This word, "geocentric," is inserted here in order to escape the criticism of the carping and captious. In oral explanation with teachers or scholars I should omit it and accept the consequences. In printed statement it is necessary to be more circumspect. If any member of a class should rise by his own exertions to an understanding of the difference between geographic and geocentric latitude, he would deserve and appreciate the fuller explanations that could be given in response to his questions; but to introduce into a first statement so fine a point as is implied in the use of geocentric would unnecessarily and unwisely delay and complicate progress.

† It is manifest that this requires observations outside of the school session and sometimes at rather inconvenient hours. But I would protest against the implication contained in objections to outside work, that lessons are so distasteful that none of the scholars will willingly give a little of their free time to such details as are here suggested. Early summer sunrise can be timed from sunset when it has been discovered during the winter that sunrise and sunset occur symmetrically before and after midday, or the moment when the sun reaches its highest altitude (meridian culmination). The general adoption of standard time introduces some confusion here, for it is desirable that sunrise and sunset should be recorded in local solar time. A watch kept to such time by observations of the sun at midday is useful in this connection. This is easily done when a north mark has once been established. The watch will then give the necessary correction for the steeple clocks and factory whistles, by which some scholars may have to make their morning and evening records.

A pocket compass for measuring the direction of sunrise and sunset may be lent to those scholars whose homes give the best view of the horizon. Compass readings should be corrected for local variation of the needle to give true bearings. The direction of early sunrise may be determined from that of late sunset when it has been discovered that the two are symmetrical with respect to the true meridian.

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girl in the land a chance to emerge from the mass, where individuality is lost, and to reach a position in which they can do the most good for themselves, their homes, and their country. The cultivation of intelligence is as essential to this end as the acquisition of knowledge. The observations and correlations now in discussion may be made to contribute usefully to both these attainments.

The sun's midday altitude should be tabulated, and the change in its value should be indicated graphically. Records thus kept are in themselves educative, not only in forming habits of accuracy and neatness, but still further in familiarizing the pupils with the several methods of record, each best for its own purpose. Graphic record may be made on a diagram in which horizontal measures represent time (dates), and vertical measures represent angular altitude. As the line connecting successive points of observation is seen to be not straight but curved, let expectation be aroused as to the probable result of further observations, thus developing the habit of thinking forward from a basis of observations in the past and present. Test the expectations by comparison with later observations, and thus develop the more important habit of not jumping at conclusions. The frequency of sun observations should be increased as the solstices are approached, in order to give good determination of those important dates. Few pupils will fail to await with interest the first observations after the Christmas holidays, or to continue observations with unflagging interest even into the hot weather of late June. It is conceivable that some children might even carry on observations of this kind through the summer vacation, in order to complete their curve for the year. A graphic bisection of the upper and lower culminations of the curve, by lines drawn through the middle points of horizontal chords, will give good determinations of the dates of the solstices. When the upper and lower limits of the curve are well determined, draw horizontal lines tangent to them, and draw a third horizontal line midway between these tangents. Lead up to the discovery that this middle line represents the sky equator; that the date of the equinoxes is given at the two intersections of the equator and the sun's path, and that the angular distance (declination) of the sun north or south of the equator can easily be roughly determined for any day of the year by measuring up or down from the equator line to the curved sun path. Then, and not properly till then, are young geographers ready to use the noon altitude and declination of the sun in determining their latitude. When this

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stage is reached, better values of the sun's declination may be taken from the Nautical Almanac for the current year, accessible in the larger public libraries. If it is not accessible there, ask the librarian to get it. The teacher of mathematics should be able to explain how to use it in finding the sun's declination on any date.

The Year.—The time and direction of sunrise and sunset should be tabulated and diagramed. The correlation of the day's length, the direction of the sun at rising and setting, and the changes in midday altitude are most instructive. Each quantity affords occasion for prediction and verification of its future values. All the changes in these quantities are run in a period of 365 days, and in the same period the star group first seen in the east shortly after sunset is again seen there at the same hour. Now let the scholars try to explain this return to a previous condition, suggesting to them that a line may be imagined starting at the sun, passing through the earth, and extending to the distant stars. This line has been found to sweep through the sky, pointing to one star group after another, and to return to the original group in the same period as that in which the noon altitude and its correlated quantities run through their variations. Then the earth must go around the sun once in 365 days. The time unit, called a year, has long been familiar to the scholars; they have probably heard or read that the earth goes around the sun in a year, but those words are now fuller of meaning than they were ever before.* The sensible constancy of the sun's diameter apparent (determined by letting a ray of sunlight pass through a pin-hole in one sheet of paper and fall upon another sheet at a fixed distance from the pin-hole) should serve to give a good idea of the form of the curve or orbit that the earth runs around.

Inclined Attitude of Axis to Orbit.—The facts regarding noon altitude and the correlated quantities can all be explained if it be suggested that the axis on which the earth has been found to turn does not stand vertical to the plane of the orbit in which it has been found to revolve. Here again a globe is of value as a mental aid and an aid in visualizing the necessary geometrical relations. So are the dia-

* In order to give a better determination of the length of the year than can be obtained merely by general inspection of the eastern constellations after sunset, the following plan may be adopted: Observations in September and October will show that the stars occupy more and more western positions at a given hour on successive evenings. Let the more skillful scholars make record of the position of some recognizable star with respect to a roof or chimney at a certain hour on a certain evening, then ask them to discover when the star will again be in that position at that hour. It will be well to have records of this sort made on several different evenings, so as to lessen the possible trouble from cloudy evenings in the following year.

grams that one usually finds in text-books, although they are much less serviceable than globes.* Whether children of under fourteen years of age can discover this solution of the problem or not remains to be proved. At least they should have a good chance to show their capacity to discover it, a carefully prepared chance, approached by the slow accumulation of pertinent observations, all familiarized by repetition.

A simple construction of the earth's orbit is also serviceable at this stage. Draw upon a sheet of paper about a foot square a line through its middle parallel to one side. Locate the middle point of the line. Construct a scale whose units are $\frac{1}{200}$ of the side of the paper, so that two pins, three units apart, can be driven into the middle line symmetrically on either side of the middle point. Lay a loop of thread or fine string 189 units in perimeter over the pins; stretch it tight with a pencil, and draw a curve thus guided. This curve shows the true pattern of the earth's orbit, the units of the scale being millions of miles. The orbit is as sensibly circular as are the earth's meridians. Take out one of the pins, and around the other draw a little circle, a trifle less than a unit in diameter, to represent the sun; a good-sized pin-head will not be much too small for it. Assuming that the North star is above the plane of the orbit (or paper), the earth moves around the orbit so as to pass from right to left when viewed from the sun. Find the point on the orbit that is nearest to the sun (it must lie where the orbit is cut by that half of the middle line which passes through the sun). Conveniently for our memories, the sun celebrates New-Year's day by passing through this near-sun point, or perihelion. July 1 sees the earth at the opposite far sun point, or aphelion. Go backward along the orbit from perihelion one-ninth of a quadrant arc; this is the point occupied on December 21, the date of the sun's least midday altitude, or the winter solstice. Draw a line from this point through the sun; it intersects the orbit at the summer solstice, which the earth passes on June 21. Draw a line through the sun at right angles to the solsticial line; it intersects the orbit in the equinoctial points. Set up a small ball on a vertical axis to represent the earth at the winter solstice; the sun can then be imagined to illuminate the near half of the earth; the day-and-night circle will separate the illuminated half from the dark half of the earth. As the earth now stands, with a vertical axis, the

* A simple, small and cheap "elementary globe," divested of nearly all names, and showing only the most general relief, is published by A. Donnelly, Oxford, N. Y.

plane of the equator passes through the sun ; but this has been shown by observation to be impossible at the time of the winter solstice. On that date the sun is 23° south of the equator. The axis of the earth must therefore be tilted 23° from the vertical and away from the sun in order to imitate actual conditions.

As the prolonged axis meets the sky in the same point at all seasons of the year, the attitude of the axis must always be parallel to its initial position. Carry the earth around its orbit, holding the axis properly on the way, and observe the relative attitude of the day-and-night circle at different times of year. All the peculiar variations of the sun's midday altitude, of the times and directions of sun rise and set, and of the length of day and night can be explained by this little working model ; hence it may be fairly said to present the conditions of nature. It is well that the scholar should know that it is entirely on the basis of such agreements between hypothesis and fact that text-books make statements about the inclination of the earth's axis, the duration of its annual revolution, and so on. There is no other door by which one can really enter the domain of knowledge, where the motto is written : " Truth for authority, not authority for truth."

When beginning to prepare this article it was my intention to cover other branches of the subject as well as those here treated, but on advancing into the manuscript it has seemed better to expand general recommendations into somewhat specific explanations in order to aid in carrying them into practice. Thus the article has grown unduly long. Something about practical exercises on the oceans and the lands may be presented at another time.

PROFESSOR HENRY ALLEN HAZEN

By a sad accident on the evening of Monday, January 22, 1900, the U. S. Weather Bureau lost one of its most prominent officials and the National Geographic Society one of its active members. Professor Hazen, while riding on his bicycle, hastening to his night work at the Weather Bureau, collided with a pedestrian and was dashed to the ground. He received injuries from which he died twenty-four hours later.

Professor Hazen was born January 12, 1849, in Sirur, India, about 100 miles east of Bombay, and was the son of Rev. Allen Hazen and Martha Chapin, his wife, missionaries of the Congregational Church. He came to this country when ten years old, and was educated at St Johnsbury, Vermont, and at Dartmouth College, where he was graduated in 1871. For some years he was instructor in

drawing in the Sheffield Scientific School, New Haven, and later was assistant in meteorology and physics under Professor Elias Loomis. He received an appointment in the Weather Bureau in May, 1881, being assigned to special duty on such problems as the investigation of the psychrometer and the proper exposures of thermometers, the study of thunderstorms, and other important questions. At a later period Professor Hazen was assigned to duties of a broader aspect, including weather forecasting and occasional editorial work on the *Monthly Weather Review*. In addition to his official work in the Weather Bureau, Professor Hazen was a frequent contributor to meteorological and other scientific journals. He was one of the supporters of *Science* during the years 1882–1889 and of the *American Meteorological Journal*, 1884–1886. Among his larger publications are the "Reduction of Air Pressure to Sea Level" and the "Climate of Chicago."

GEOGRAPHIC MISCELLANEA

THE Peary Arctic Club (Brooklyn, N. Y.) in recording its admiration for Mr Peary's activity and persistence has pledged its unfaltering support to the remaining work of the expedition.

NOTWITHSTANDING the greatly increased cost, both of materials and labor, the shipbuilding output of Great Britain in 1899 was the largest on record, having reached the enormous total of 1,713,000 tons. Preliminary returns place the year's output in Germany at 257,927 tons, in the United States at 178,636 tons, and in France (the only other country exceeding 50,000 tons) at 60,586 tons.

A RECENT number of *Science* announces that an expedition organized by Baron Toll for the exploration of the New Siberia Islands and Saunikoff Land, into which no man has yet penetrated, will set out in June next from some Norwegian port. The party will pass the winter at a point on the banks of the Lena, above the town of Yokutsk, and in the summer of 1901 will begin their explorations toward the north.

MR E. H. Harriman, the patron of the expedition to Alaska which bears his name, will publish the results of the expedition in a series of several volumes prepared under the general editorial management of Dr C. Hart Merriam. The first volume is to be a narrative of the expedition by John Burroughs, with a chapter on glaciers by John Muir, and other chapters by well-known writers. The scientific results, comprising several separate volumes, are being prepared by the specialists who had charge of the different branches of work.

SOME months since the French Government, according to the *Le Tour Du Monde*, instructed P. Froc, director of the meteorological observatory near Shanghai, to choose some site in the French Indo-China colony and there establish a meteorological observatory. The director has chosen for the purpose a slight elevation near Tonkin called Kalan, which is only 400 feet high. The hill is near the sea, and the neighboring hills which encircle it form a sort of

enclosure, which is peculiarly sensitive to all the phenomena of the surrounding country, and also to the slightest disturbance from the sea. The observatory will thus have a maritime as well as a meteorological value.

THE project of maintaining the level of Lake Erie near its high-water stage during the navigation season by constructing a dam across Niagara River below Buffalo harbor is reported by the Deep Water Ways Commission as practicable and desirable. Thus the water lost by evaporation in summer could be partially replaced by accumulating the surplus water during the closed season and releasing it when most necessary in the open season. The best location for a dam is, according to the board, at the foot of the lake, just below Buffalo harbor. A canal with a lock is provided on the American side around the end of the dam and the rapids at the head of the river. The cost of the regulating works is estimated at $796,923, and of the lock and canal at $2,325,967. The changes would raise the low-water stage about three feet in Lake Erie, two feet in Lake St Clair, and one foot in Lake Huron.

THE U. S. Commercial Agent at Vladivostock, Mr Richard T. Greener, reports that it is proposed to turn the military port of Vladivostock into a commercial port, making it the principal terminus of the Trans-Siberian Railroad. Port Arthur will then become the chief military port of eastern Siberia. Talienwan, which has been renamed "Dalny," will be the commercial port, and an "open" one, of the Pechili Gulf. Every effort will be made to make it an important trade center. The plans of streets, government buildings, etc., are already formulated and will be put in execution, while the construction of the various lines of railroad is also being pushed to completion. The plan of the Russian government to form an eastern Asiatic steamship company to open communication between Port Arthur, the Manchurian Railroad, Vladivostock, and other ports of the Far East is now arranged. The service between Vladivostock and Port Arthur will soon be begun.

THE *Manual of Tides* now being prepared in the Coast and Geodetic Survey Office by Dr R. A. Harris will discuss, among other subjects, the tidal theory. So far as the study of the tidal oscillations in the great oceanic basins has progressed, it tends to show that the dominating tides of most localities owe their origin to one of two methods of generation. The first is that implied in the corrected equilibrium theory, and pertains to rather small and well enclosed bodies of water; the second, and far more important, method is that implied in stationary oscillations whose free periods approximately coincide with the periods of the tidal forces. As an example of these oscillating areas may be cited the region lying south of the Maine coast, from Nantucket to the southern end of Nova Scotia. Following a line, somewhat convex, toward the south, joining these two points, there appears to be a small tidal disturbance, probably not more than two feet, whereas along the entire New England coast, north of Nantucket, the tides are in the neighborhood of from eight to ten feet. Moreover, on this nodal line just mentioned, running from Nantucket to Nova Scotia, the currents are well pronounced, so that it appears that we have here an area which oscillates about the nodal line as an axis, thus producing high water at practically the same time along the New England coast.

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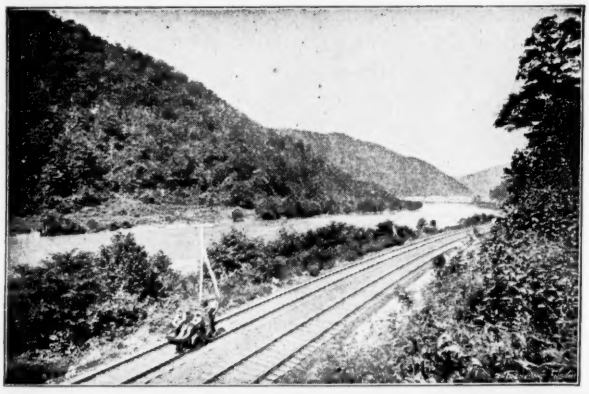

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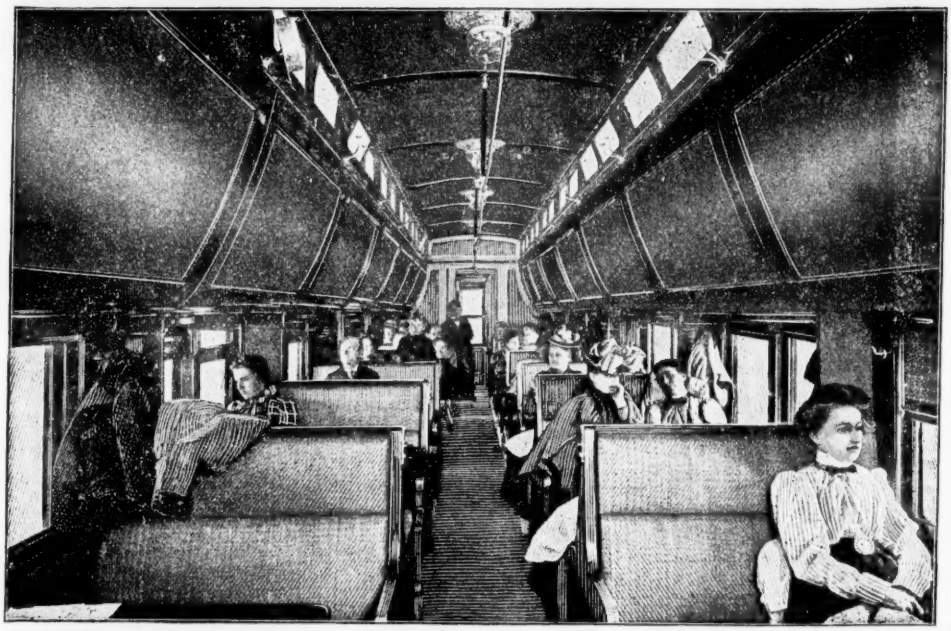

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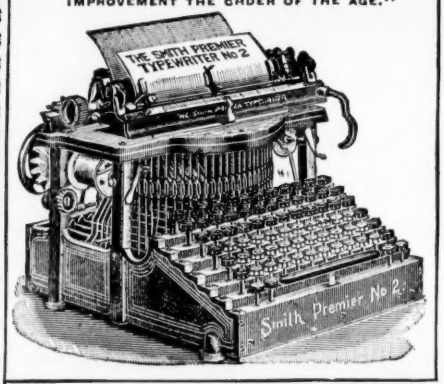

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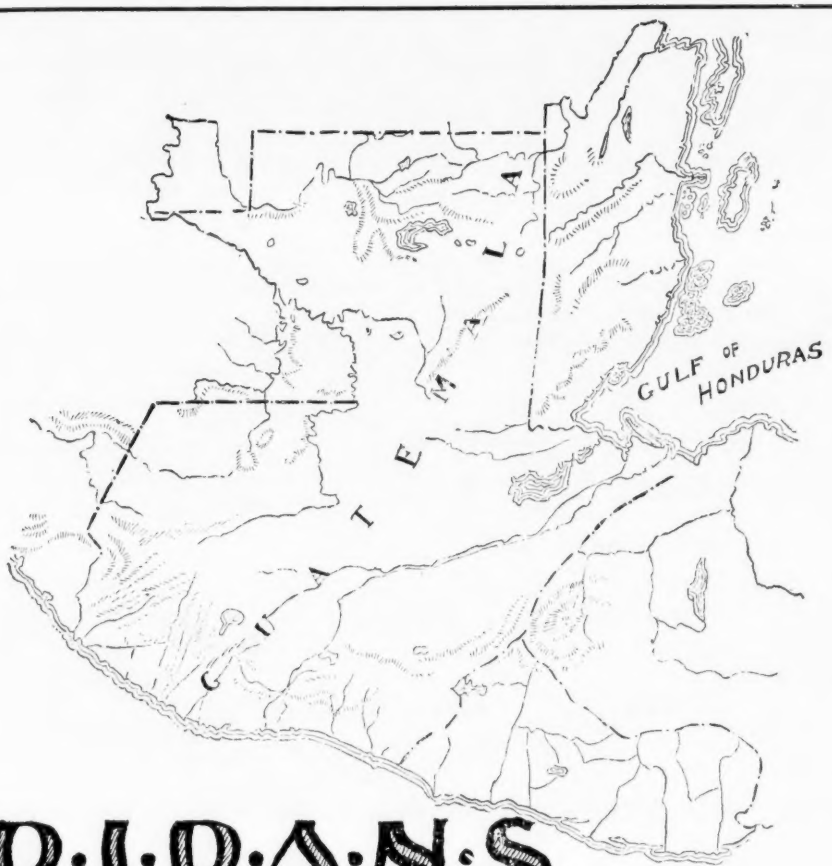

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